

Beagle 2: The Next Exobiology Mission to Mars

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Beagle 2 is a 60 kg probe (with a 30 kg lander) developed in the United Kingdom for inclusion on the European Space Agency's 2003 Mars Express. Beagle 2 will deliver to the Martian surface a payload which consists of a high percentage of science instruments to landed spacecraft mass. Beagle 2 will be launched in June, 2003 with Mars Express on a Soyuz-Fregat rocket from the Baikonur Cosmodrome in Kazakhstan. Beagle 2 will land on Mars on December 26, 2003 in the Isidis Planitia basin ($\sim 10^{\circ}\text{N}$ and 275°W), a large sedimentary basin that overlies the boundary between ancient highlands and northern plains. Isidis Planitia, the third largest basin on Mars, which is possibly filled with sediment deposited at the bottom of long-standing lakes or seas, offers an ideal environment for preserving traces of life.

Beagle 2 was developed to search for organic material and other volatiles on and below the surface of Mars in addition to the study of the inorganic chemistry and mineralogy [1]. Beagle 2 will utilize a mechanical mole and grinder to obtain samples from below the surface, under rocks and inside rocks. A pair of stereo cameras will image the landing site along with a microscope for examination of surface and rock samples. Analyses will include both rock and soil samples at various wavelengths, X-ray spectrometer and Mossbauer spectrometer as well as a search for organics and other light element species (e.g. carbonates and water) and measurement of their isotopic compositions. Beagle 2 has as its focus the goal of establishing whether evidence for life existed in the past on Mars at the Isidis Planitia site or at least establishing if the conditions were ever suitable. Carbonates and organic components were first recognized as existing on Mars when they were found in the Martian meteorite Nakhla [2,3]. Romanek et al. [4] showed the carbonates in ALH84001 were formed at low temperatures. McKay et al. [5] noted possible evidence of early life on Mars within the

ALH84001 meteorite. Thomas-Keptra et al. [6] showed the magnetite biomarkers in ALH84001's carbonates are indistinguishable from those formed by magnetotactic bacteria found on Earth. Gibson et al. [7] showed there was significant evidence for liquid water and biogenic products present on Mars across a 3.9 billion year period.

A mechanical arm (PAW) operates from the lander and is used for science operations along with sample acquisition. Instruments attached to the PAW include: stereo cameras, Mossbauer instrument, X-ray fluorescence instrument, microscope, environmental sensors, rock corer/grinder, a spoon, mirror, brushes, a mole attachment for acquisition of subsurface to depths of 1 to 2 meters and an illumination device. Each camera has 14 filters which have been optimized for mineralogy composition, dust and water vapor detection. The microscope's camera is designed for viewing the size and shape of dust particles, rock surfaces, microfossils, and characteristics of the samples prior to introduction into the gas analysis package (GAP). The camera has a resolution of 4 microns/pixel, features 4 color capability (red, green, blue and UV fluorescence), a depth of focus of 40 micrometers and translation stage of ± 3 millimeters.

The heart of the Beagle 2's life detection package is the gas analysis package (GAP) which consists of a mass spectrometer with collectors at fixed masses for precise isotopic ratio measurements and voltage scanning for spectral analysis. Primary aim of the GAP is to search for the presence of bulk constituents, individual species, and isotopic fractionations for both extinct and extant life along with studying the low-temperature geochemistry of the hydrogen, carbon, nitrogen and oxygen components on Mars from both the surface and atmosphere. GAP is a magnetic sector mass spectrometer with the range of 1 to 140 amu which can be operated in both the static and dynamic modes. A triple Faraday collector array will be used for C, N and O ratios along with a double Faraday array for H/D. Pulse counting electron multiplier will be utilized for noble gases and selected organics. Anticipated detection limits are at the picomole level for operation in the static mode of operation and high precision isotopic measurements will be made in the dynamic mode. Sample processing and preparation system consists of reaction vessels along with references. Sample ovens capable of being heated are attached to the manifold for sample combustion. Surface, subsurface materials and interior rock specimens will be combusted in pure oxygen gas at various temperature intervals to release organic matter and volatiles. Combustion process will permit detection of all forms and all atoms of carbon present in the samples. A chemical processing system is capable of a variety of conversion reactions. Gases are manipulated either by cryogenic or chemical reactions and passed through the gas handling portion of the vacuum system. There are two modes of operation: quantitative analysis and precise isotopic measurements.

Three main types of analysis will be carried out by the GAP: (1) search for organic matter, (2) stepped combustion for total light element content and speciation, and (3) atmospheric analysis. Isotopic measurement of H/D, $^{13}\text{C}/^{12}\text{C}$, $^{15}\text{N}/^{14}\text{N}$, $^{17}\text{O}/^{16}\text{O}$, and $^{18}\text{O}/^{16}\text{O}$ and search for possible biogenic methane within the Martian atmosphere will be made. Estimates of the present methane concentration in the atmosphere is believed to be <100ppb. Lifetime of CH_4 in Mars' atmosphere is believed to be < 300 years and therefore no abiogenic methane is anticipated. The GAP is capable of concentrating

gases and the search for biogenic atmospheric methane will be made. The mass spectrometer will operate in the static mode for the CH₄ measurements after chemical reagents have concentrated the atmospheric gases. Conversion to a measureable component will be carried out to ensure no false positive results will be obtained along with lowering the detection limits for methane. Should methane be detected within the Martian atmosphere its putative source would have to be biogenic (i.e. methanogenic bacteria).

An environmental sensor system for surface temperatures, atmospheric pressures, wind speed and direction is also to accompany atmospheric sampling. Particle radiation environment's dose and rates will be characterized. UV flux at the lander will be measured in a variety of wavelength bands longer than 200nm, information relevant to understanding the survival of organics. High sensitivity isotopic analysis of the carbon species present within the samples makes no assumptions about the biochemistry on Mars but provides clues to past life as inferred from the isotopic fractionations measured directly on Mars. Isotopic fractionation signatures from biogenic processes will survive even in altered rocks. Planetary protection protocols will be followed for Beagle 2. The lander has been designated as a Category IVA⁺ mission. A microbial reduction plan is in place and all components will be sterilized. Additional cleaning procedures will be followed to reduce blanks associated with GAP operations.

References: [1] M.R. Sims et al. (1999), *SPIE Conf. on Instruments, Methods and Missions for Astrobiology II*, SPIE Vol. 3755, pp. 10-23. [2] R. Carr et al. (1985) *Nature* 314, 248-250. [3] I.P. Wright et al. (1989) *Nature* 340, 220-222. [4] C.S. Romanek et al. (1994) *Nature* 372, 655-657. [5] D.S. McKay et al. (1996) *Science* 273, 924-930. [6] K. Thomas-Keprta (2000) *Geochimica et Cosmochimica Acta* 64, 4049-4081. [7] E.K.Gibson, Jr. et al. (2001) *Precambrian Research* 106, 15-34.